Estimating and predicting FF CO_2 fluxes using top-down NOx emissions and CO_2 observations and inventories
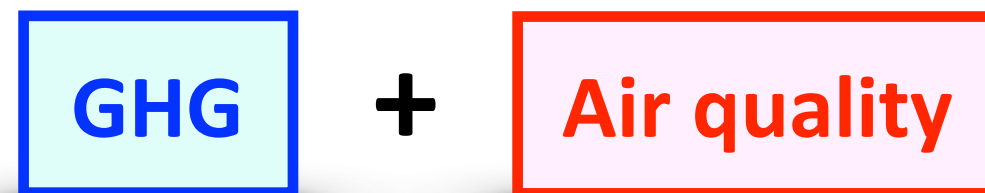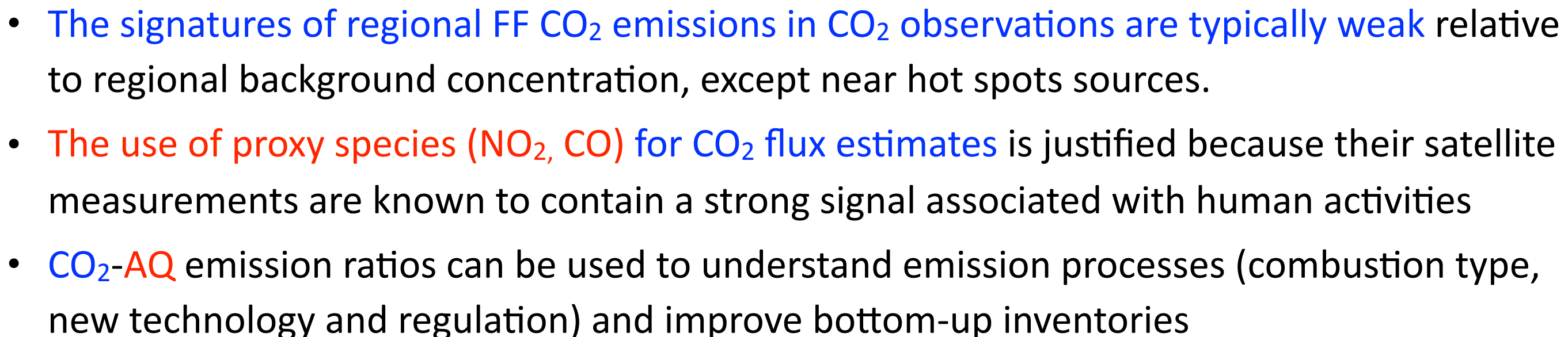
GHG + Air quality

Kazuyuki Miyazaki, Kevin Bowman

Jet Propulsion Laboratory, California Institute of Technology

GHG + **Air quality**

- OH coupling (CH_4)
- Combustion process (NOx, CO, CO_2)
- Joint emission optimization

Reuter et al., 2019
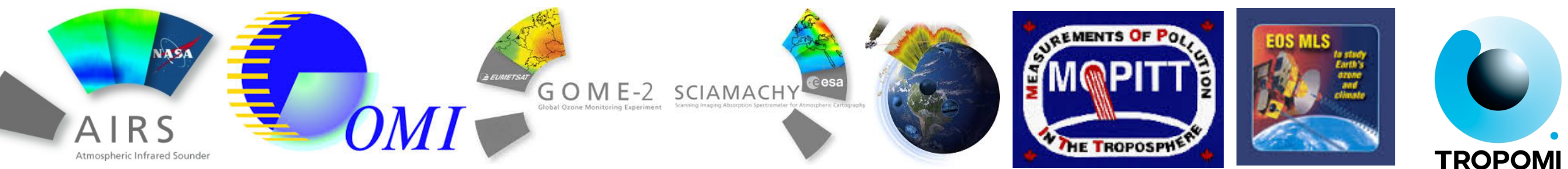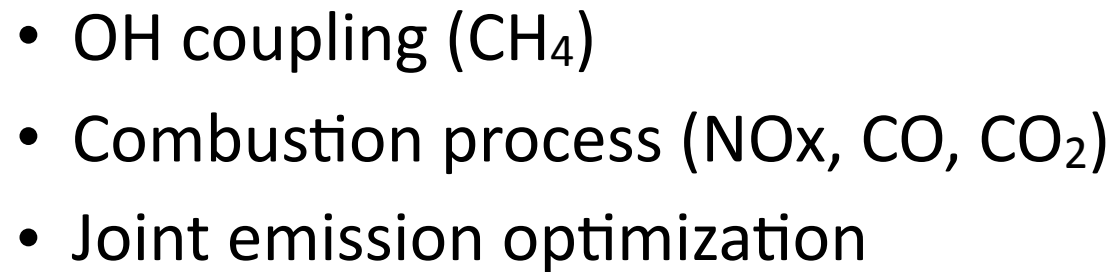
Monitoring localized CO_2 emissions:
co-located regional CO_2 (OCO-2)
and NO_2 (S5P) enhancements

- The signatures of regional FF CO_2 emissions in CO_2 observations are typically weak relative to regional background concentration, except near hot spots sources.

- The use of proxy species (NO_2, CO) for CO_2 flux estimates is justified because their satellite measurements are known to contain a strong signal associated with human activities

- CO_2-AQ emission ratios can be used to understand emission processes (combustion type, new technology and regulation) and improve bottom-up inventories

GHG	+	Air quality

Hybrid FF CO_2 emissions using **AQ measurements**

Konovalov et al., 2016, ACP

1. Top-down NOx and CO emission estimates using satellite measurements
2. Apply emissions factors (NOx/CO_2 ratios from bottom-up inventories) to relate FF CO_2 emissions to the NOx emissions

strongly rely on top-down NOx emission estimates and emission ratios in bottom-up inventories

Characterizing regional-scale combustion using CO, NO$_2$, and CO_2 obs
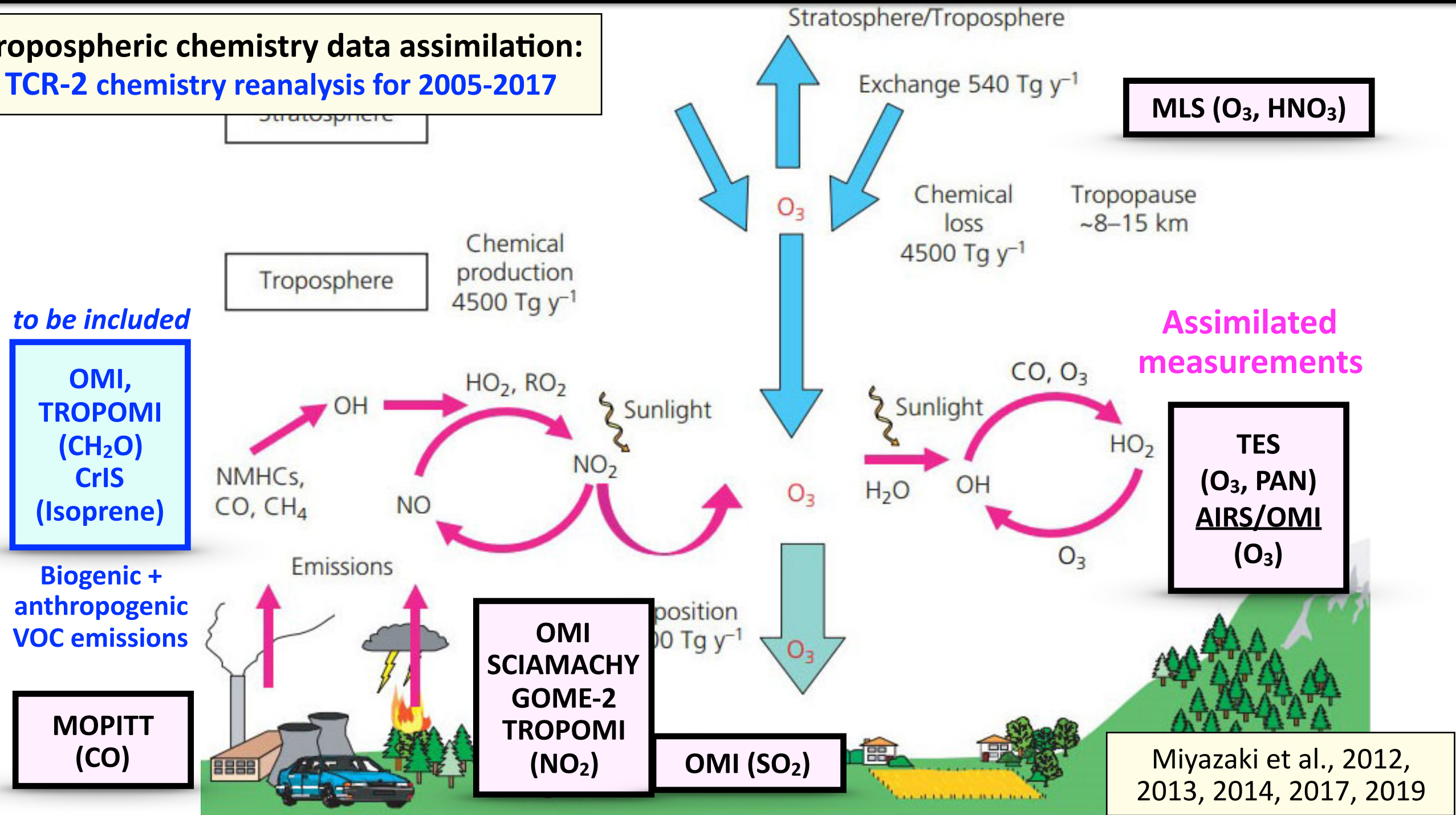
- Satellite observations of the CO-NO_2-CO_2 ratio patterns are able to distinguish between combustion types. There is no distinction between the various developed and developing regions in bottom-up inventories.
- Multi-species observations can provide constraints on emission inventories, and be useful in monitoring trends and understanding combustion.

Silva and Arellano, 2017

Hybrid FF CO$_2$ emission estimates using improved NOx emissions

1. Temporal evolutions of top-down NOx emissions and CO$_2$ emission inventories
2. Understand long-term changes in emission ratios and emission processes
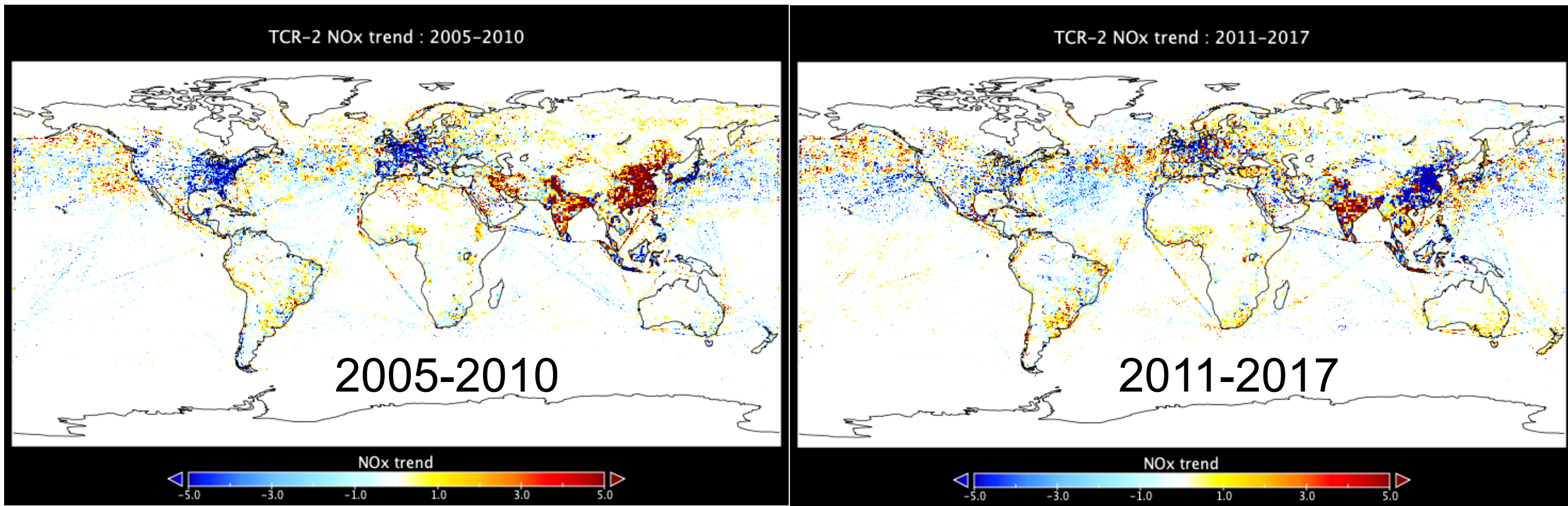3. Predict CO$_2$ fluxes using emission ratio trajectories and up-to-date NOx emissions

Tropospheric chemistry data assimilation:
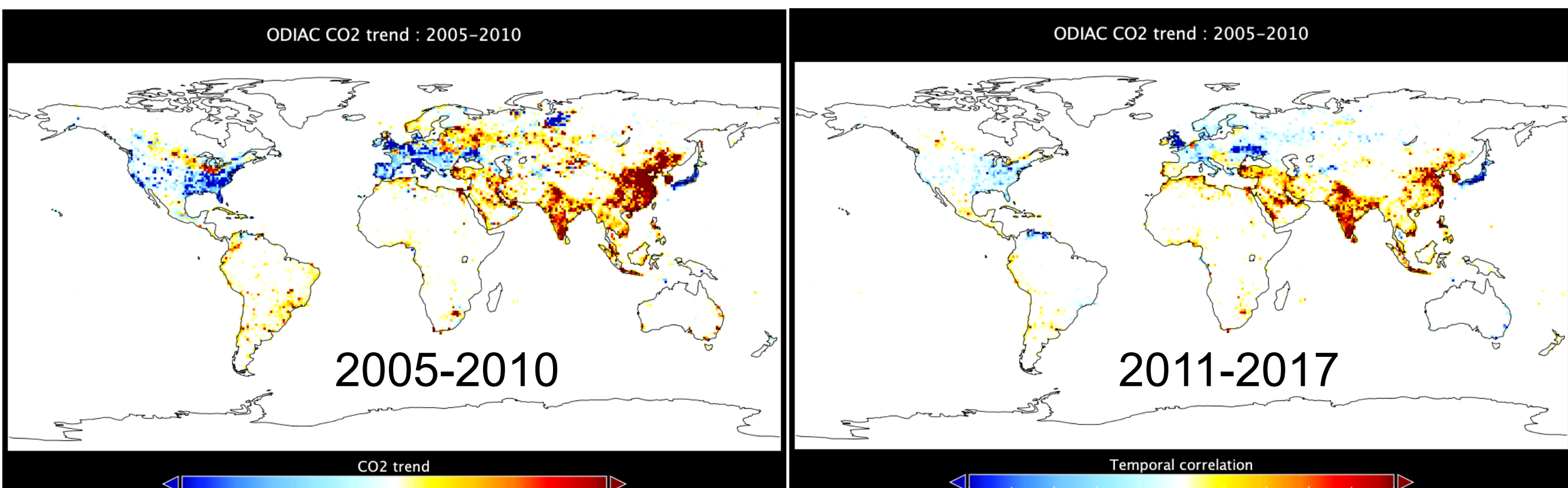**TCR-2 chemistry reanalysis for 2005-2017**

to be included

OMI, TROPOMI (CH$_2$O) CrIS (Isoprene)

Biogenic + anthropogenic VOC emissions

MOPITT (CO)

MLS (O$_3$, HNO$_3$)

Assimilated measurements

TES (O$_3$, PAN) AIRS/OMI (O$_3$)

OMI SCIAMACHY GOME-2 TROPOMI (NO$_2$)

OMI (SO$_2$)

Miyazaki et al., 2012, 2013, 2014, 2017, 2019

→ improve NOx, CO, SO$_2$ emission estimates with reduced model errors unrelated to emissions

Hybrid FF CO₂ emission estimates using improved NOx emissions

TCR-2 NOx trend

TCR-2 NOx trend : 2005-2010

2005-2010

NOx trend
-5.0   -3.0   -1.0   1.0   3.0   5.0

TCR-2 NOx trend : 2011-2017

2011-2017

NOx trend
-5.0   -3.0   -1.0   1.0   3.0   5.0

ODIAC CO₂ trend

ODIAC CO2 trend : 2005-2010

2005-2010

CO2 trend

ODIAC CO2 trend : 2005-2010

2011-2017

Temporal correlation

Hybrid FF CO$_2$ emission estimates using improved NOx emissions

How will changes in air quality mitigation impact carbon emissions?

AQ/Carbon co-evolution

NO$_2$ trend (TgN/yr)

Q2   Q1

Q4   Q3   CO$_2$ trend (TgC/yr)
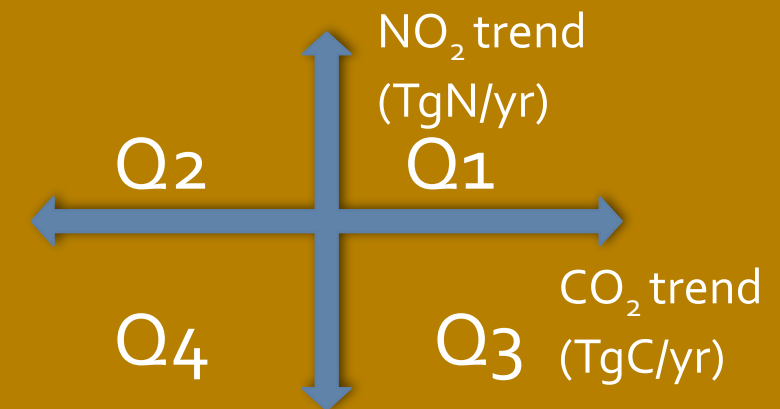
Q1: Business as usual (BAU)
Q2: Carbon-only
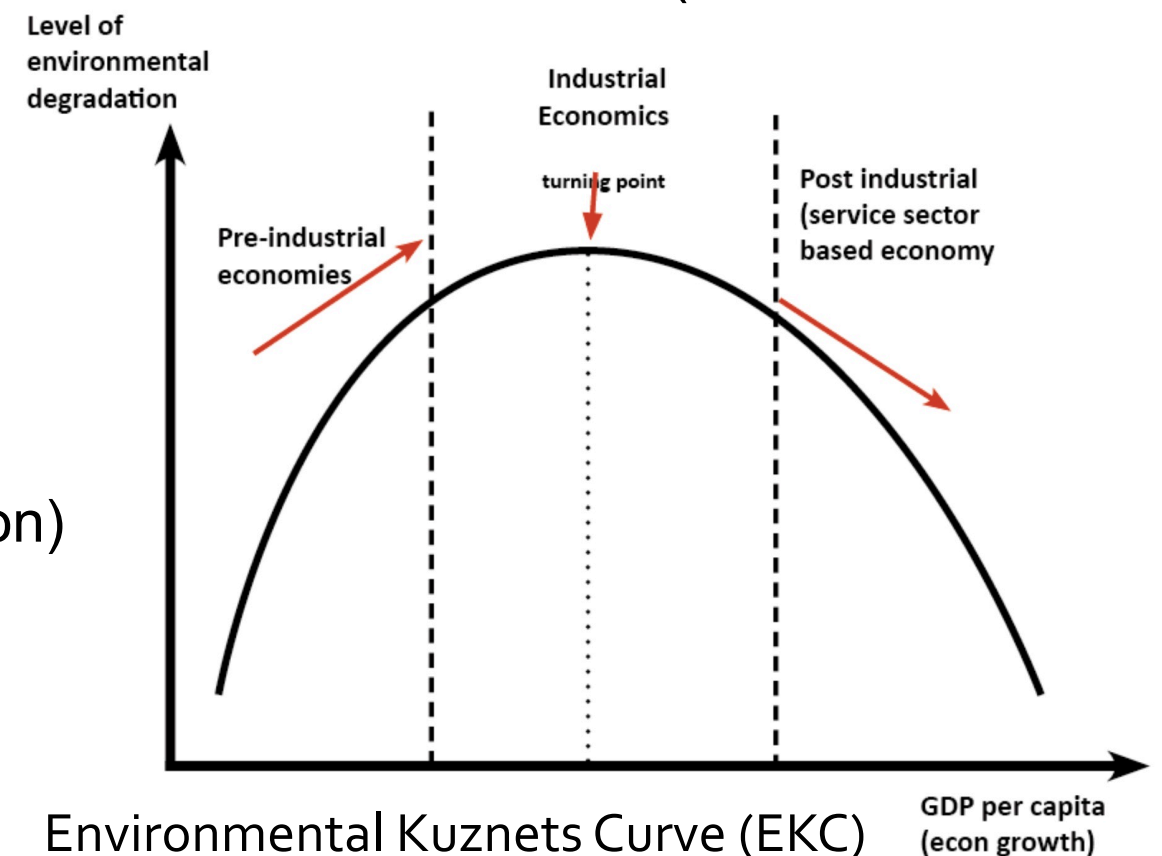Q3: AQ-only (CO$_2$ lock-in?)
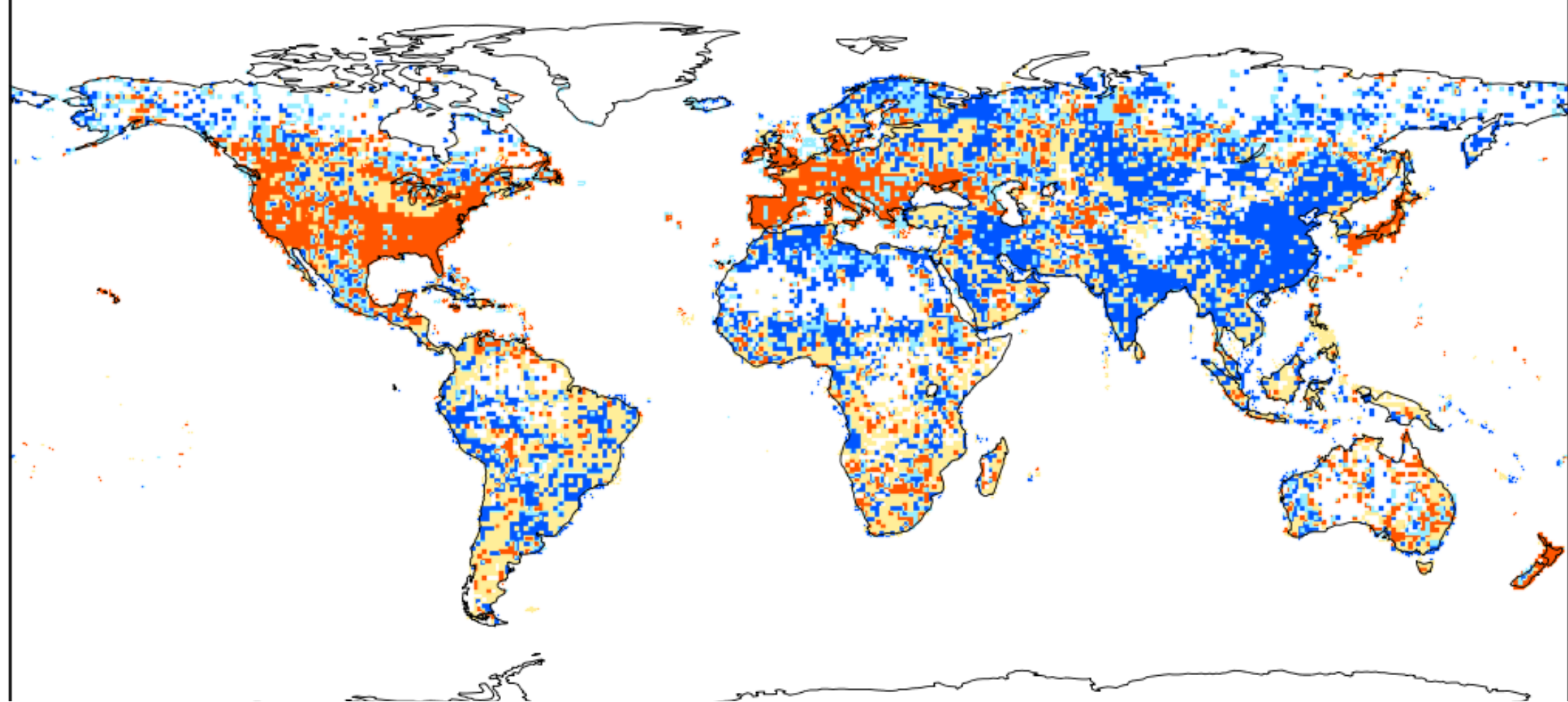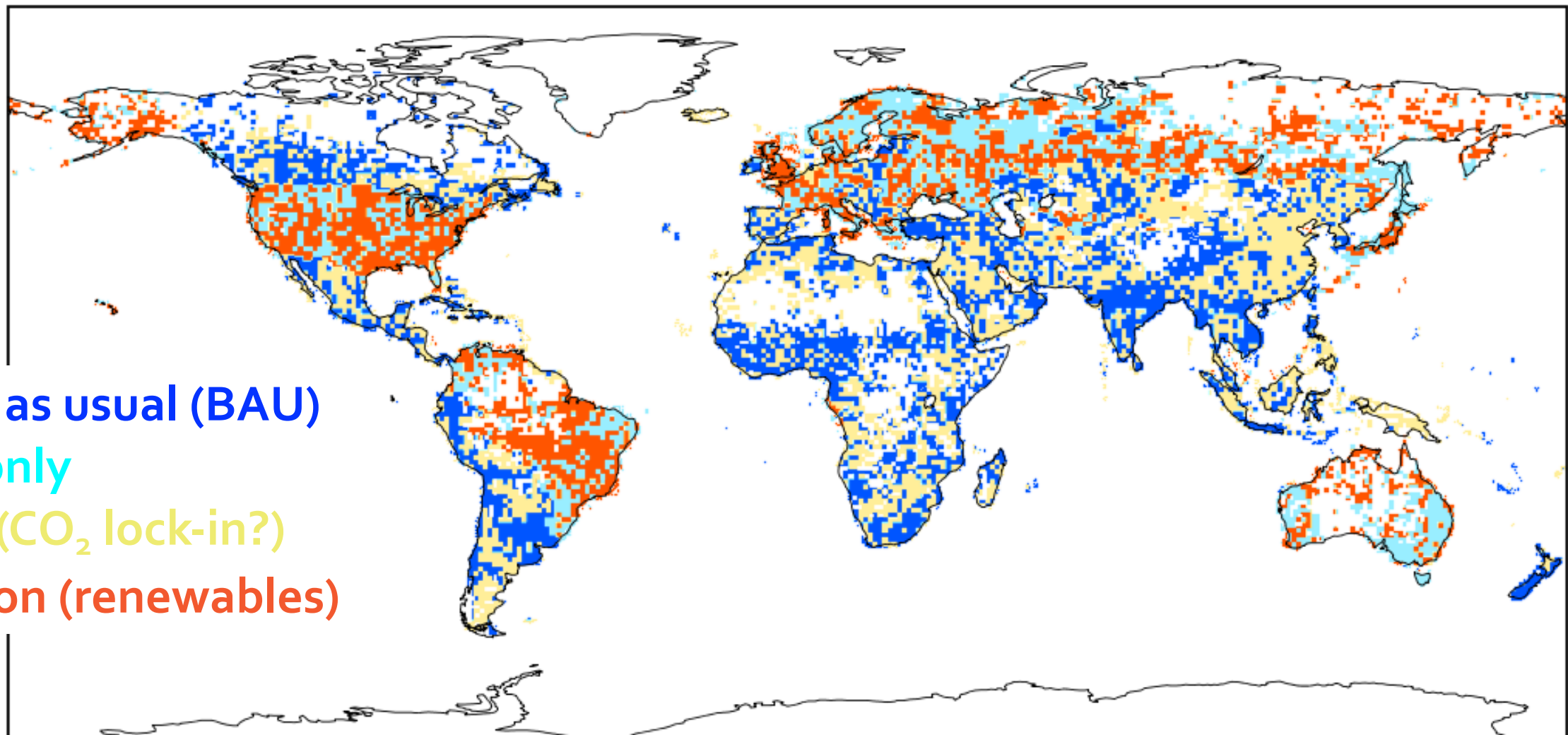Q4: AQ/Carbon co-reduction (renewables)

(from K. Bowman)

China   Q1→Q3
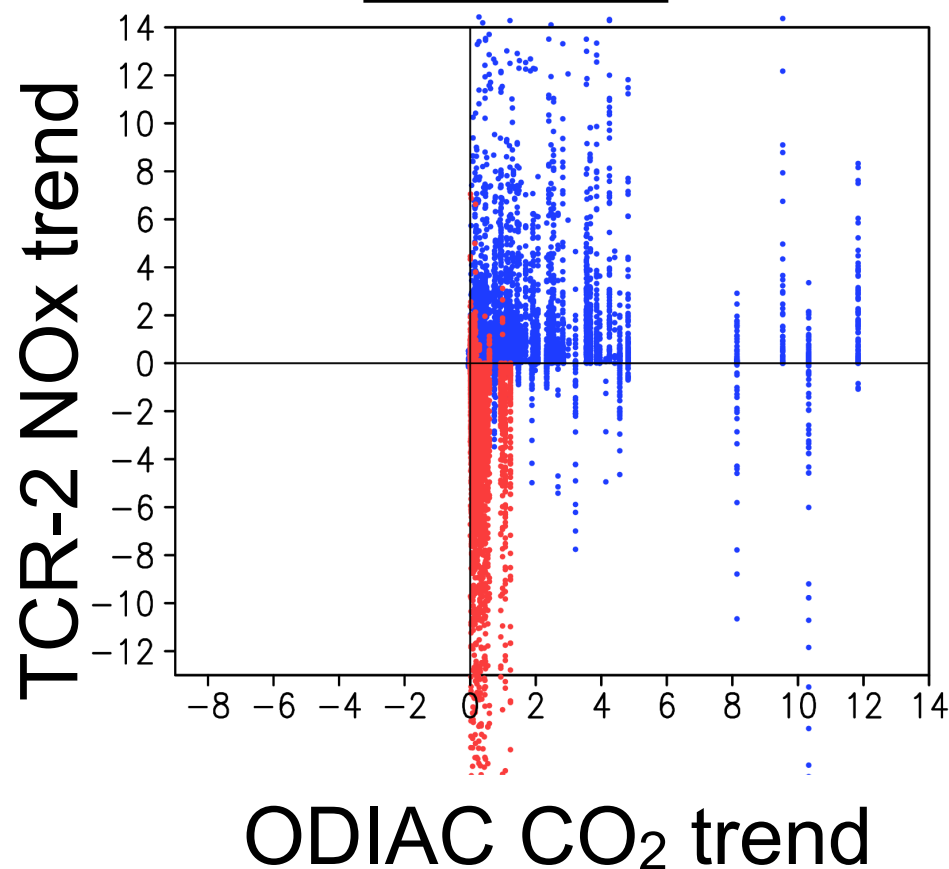
2005-2010
2011-2017
(Road transportation)

TCR-2 NOx trend

ODIAC CO$_2$ trend

Level of environmental degradation

Industrial Economics

turning point

Pre-industrial economies

Post industrial (service sector based economy)

GDP per capita (econ growth)

Environmental Kuznets Curve (EKC)

2005-2010

2011-2017

Q1: Business as usual (BAU)
Q2: Carbon-only
Q3: AQ-only (CO_2 lock-in?)
Q4: AQ/Carbon (renewables)

Hybrid FF CO₂ emission estimates using improved NOx emissions

- ○ ODIAC CO2
- ○ ODIAC CO2 (predicted from a 2011-2016 NOx-CO2 linear regression)
- ○ TCR NOx

(Kuwait)

Hybrid FF CO_2 emission estimates using improved NOx emissions

- ODIAC CO2
- ODIAC CO2 (predicted from a 2011-2016 NOx-CO2 linear regression)
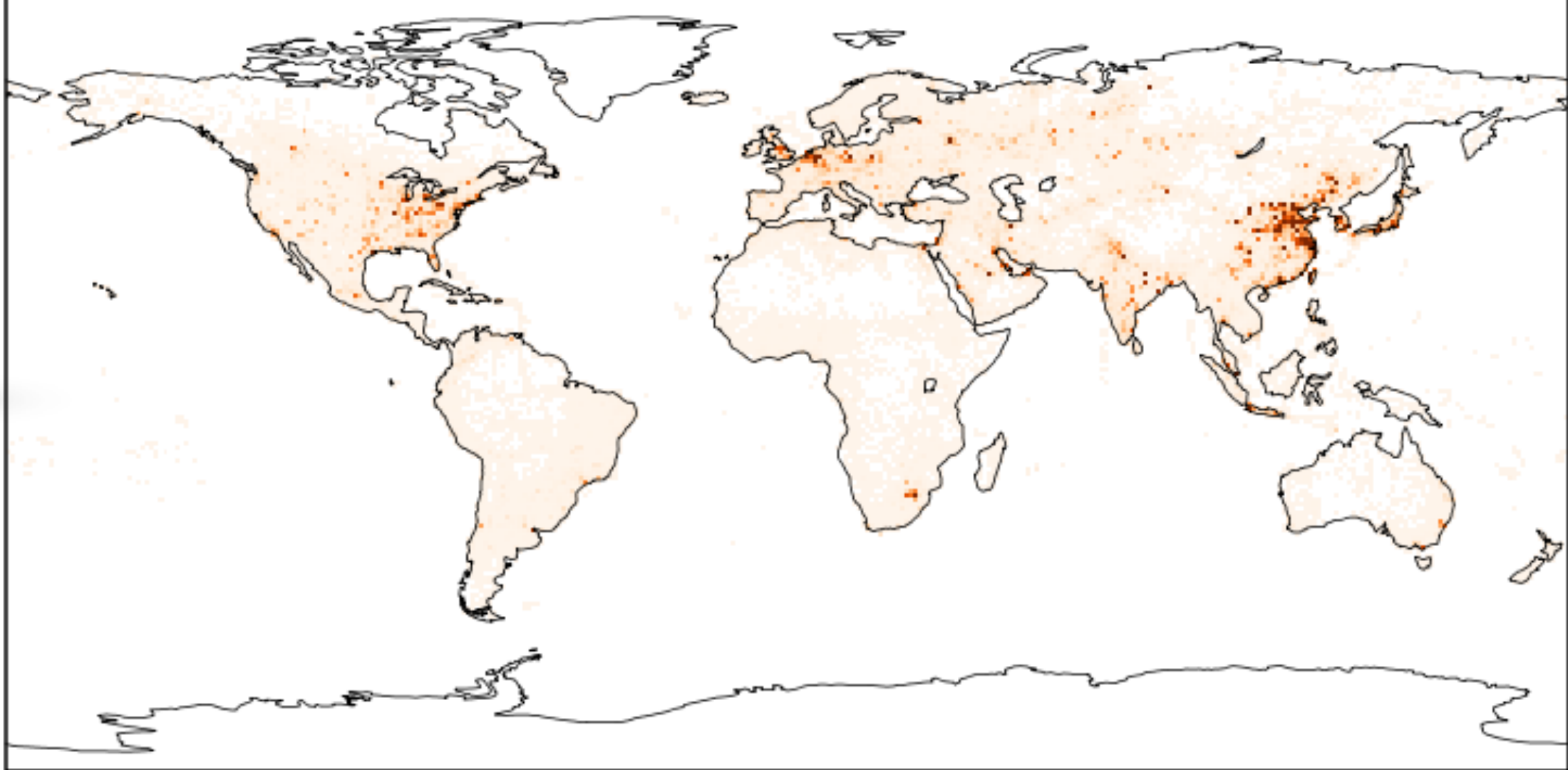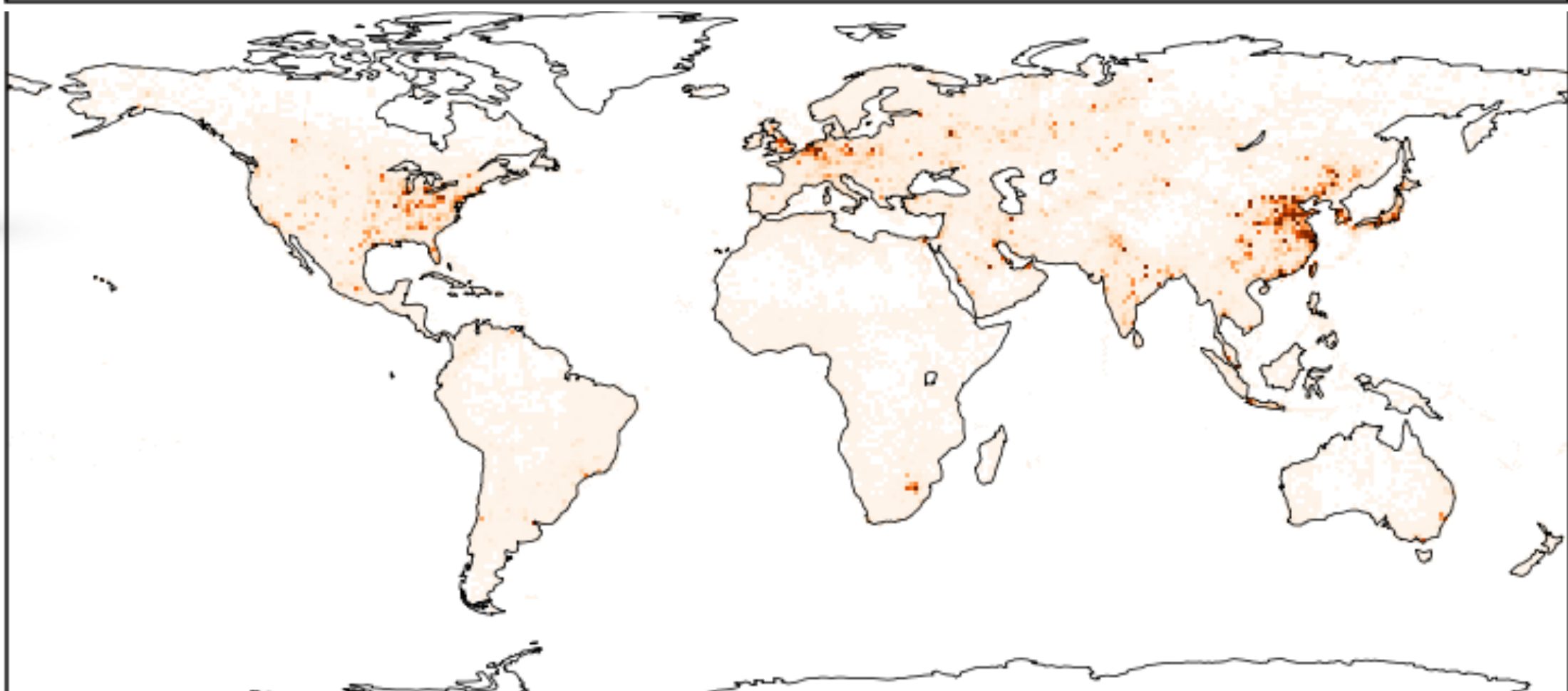- TCR NOx

(Kuwait)
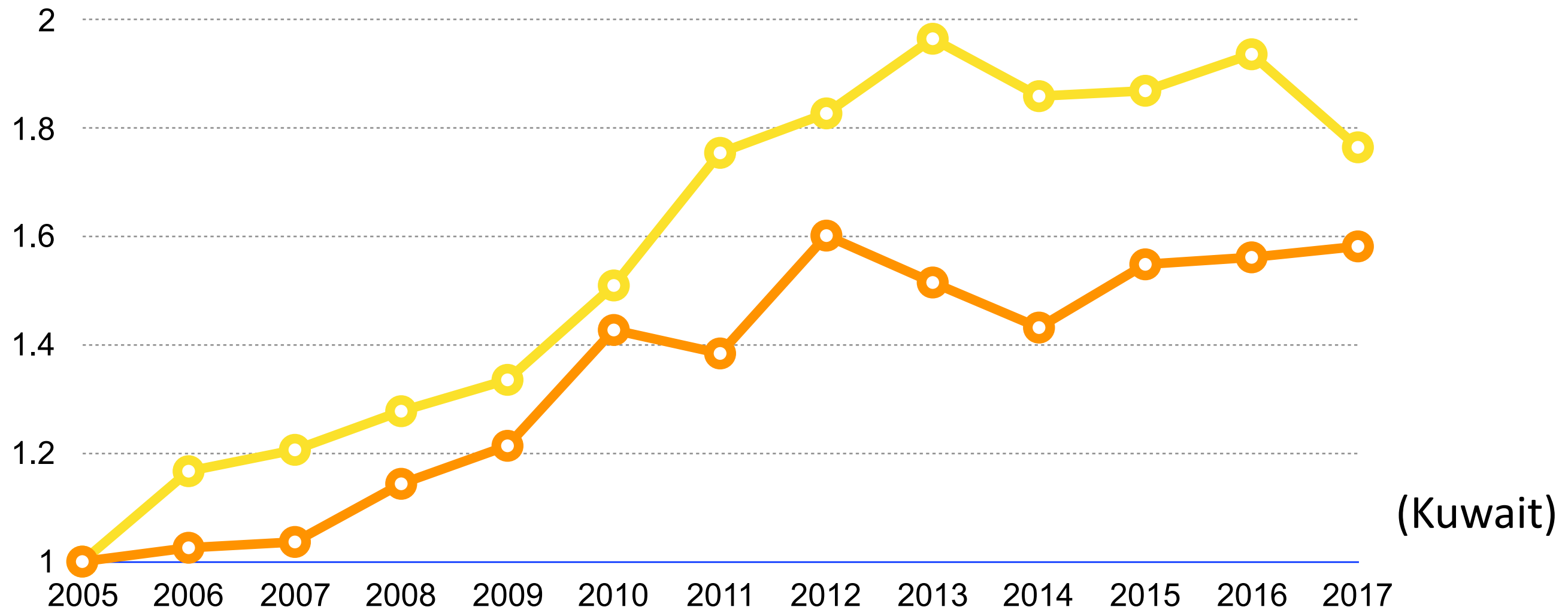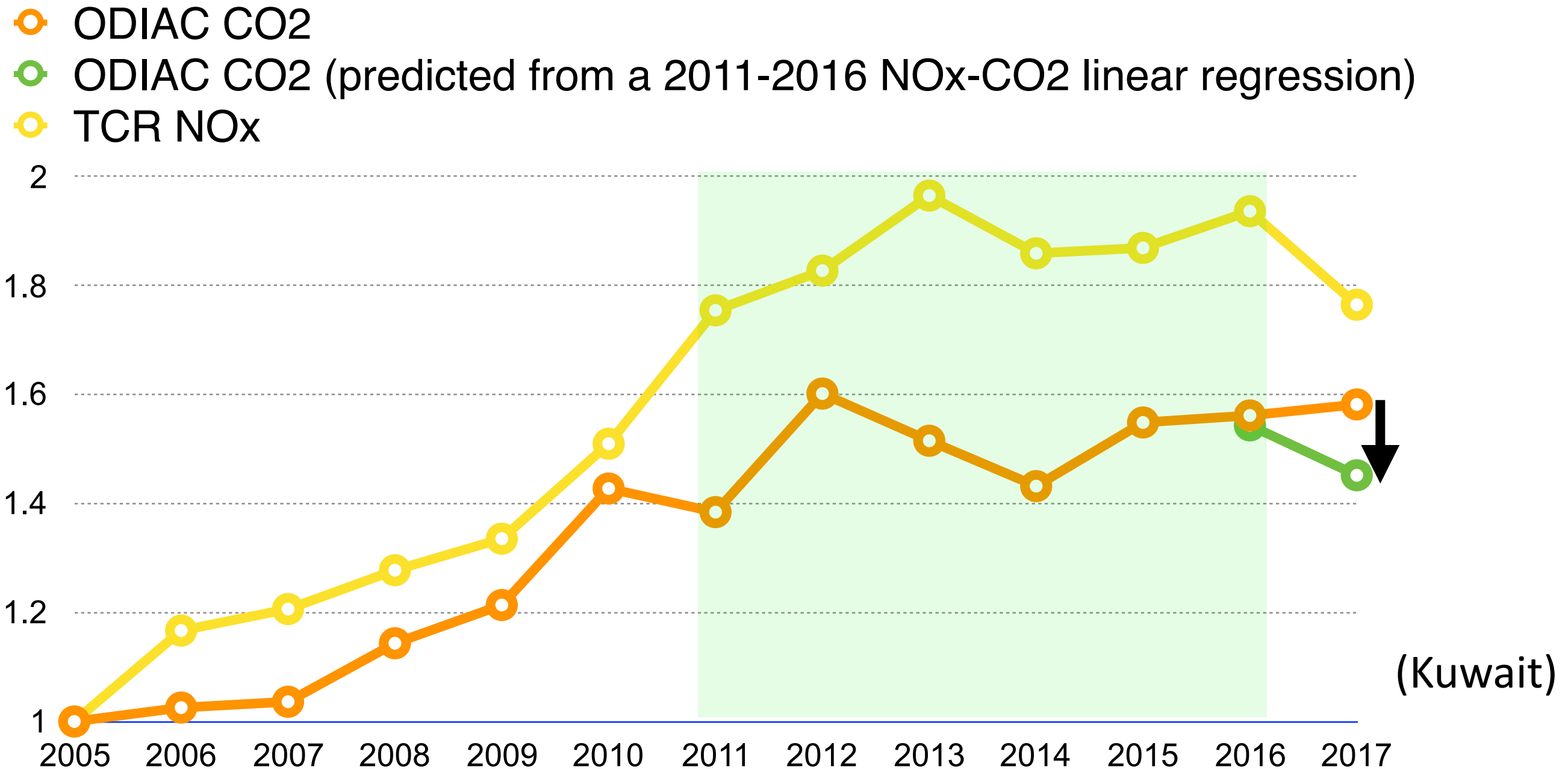
→ Implications for changes in emission factors and activity

Implementation of new technology and regulation?

ODIAC
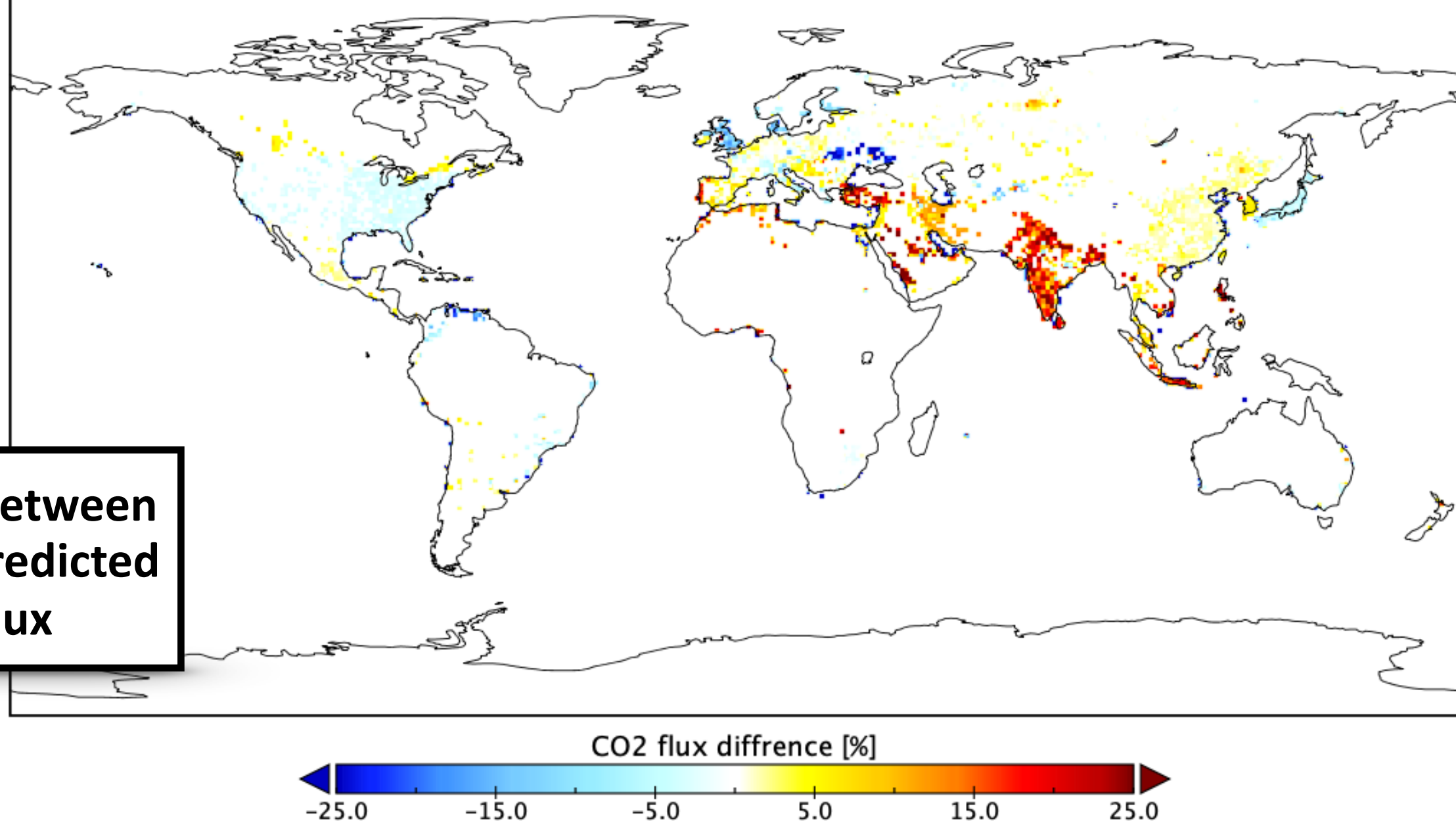
Predicted

2017

Differences between ODIAC and predicted FF CO_2 flux

CO2 flux diffrence [%]

-25.0   -15.0   -5.0   5.0   15.0   25.0

Strong year-to-year variations in emission factors, activity, and emission ratios for India, SE Asia, and the Middle east?

→ *improvements of emission inventories, understanding of emission processes*

By making an emission ratio trajectory (temporally varying) and using up-to-date NOx emission estimates (- a week delay), we could obtain near-real time FF CO_2 fluxes, without waiting for statistical information needed for FF CO2 inventories!

Multi-species (NOx + CO + SO$_2$) constraints on FF CO$_2$ flux

Different aspects of the combustion technology are expected to affect those emissions in different ways: e.g., NOx emissions are strongly dependent on the temperature of combustion (more NOx is released at higher T), CO emissions can be regarded as a measure of the incompleteness of combustion processes. Strong SO$_2$ emissions from volcanic eruptions.

Listing strong emission points using top-down NOx emissions

Strong FF emission points from top-down estimates

→ **Any missing points in the OCO-3 ODIAC target list?**
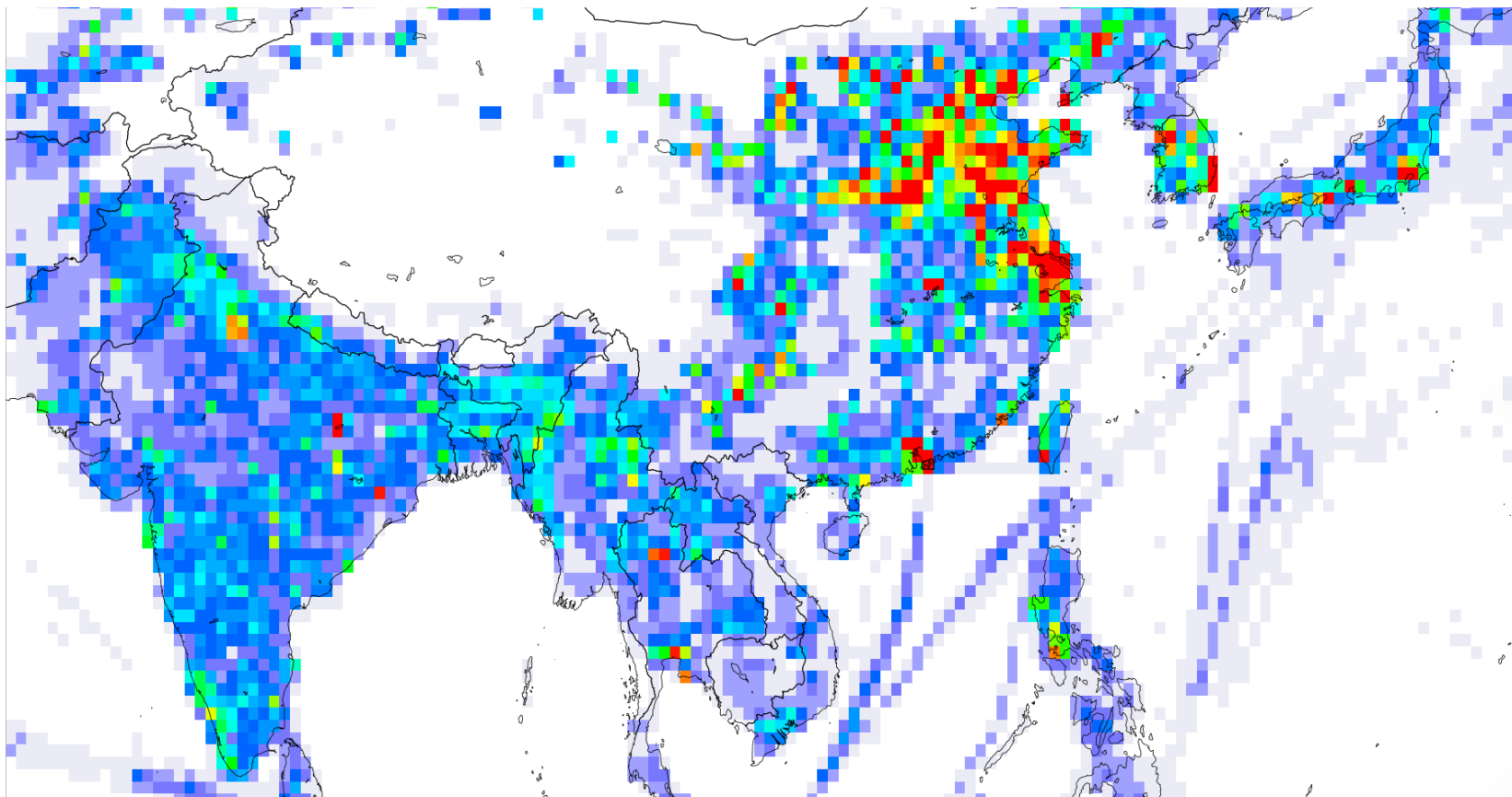
High resolution global data assimilation of TROPOMI NO$_2$

+ **Joint emission estimation**

OCO-3 CO$_2$